"Feldspar Aggregate Occurring in Nelson County, Virginia," W. M. Thornton, Jr.

"History of the Coconut Palm in America," O. F. Cook.

"New Mink from the Shell Heaps of Maine," F. B. Loomis.

THE first number of the new journal, *Phytopathology,* has just appeared. This periodical is the official organ of the American Phytopathological Society. It is to be published bimonthly and to be devoted to both the purely scientific and practical economic features of plant disease investigations. The chief editors are Dr. L. R. Jones, professor of plant pathology, University of Wisconsin; Dr. C. L. Shear, plant pathologist, U. S. Department of Agriculture, and Professor H. H. Whetzel, professor of plant pathology, Cornell University; who are assisted by twelve associate editors, representing different institutions and sections of the country. The initial number contains 37 pages and 6 plates. An excellent portrait of Anton de Bary, hitherto unpublished, appears in the frontispiece. The following articles are included:

"Anton de Bary" (with portrait), Erwin F. Smith.

"The Rusts of White and Red Clover," Frank D. Kern.

"Crown Gall of Plants," Erwin F. Smith.

"Fig Diseases," C. W. Edgerton.

"Floret Sterility of Wheats in the Southwest," Edw. C. Johnson.

"Black-leg or Phoma Wilt of Cabbage," Thos. F. Manns.

"A New Fruit Spot of Apple," W. M. Scott.

Reviews.

SPECIAL ARTICLES

A KINETIC THEORY OF GRAVITATION[1]

EVER since Sir Isaac Newton enunciated the law of universal gravitation, more than two hundred years ago, philosophers have speculated on the nature of the mysterious agency which links every atom of matter in the universe with every other atom. Newton was unable to offer any adequate explanation.

Since Newton's time several theories of gravitation have been proposed, but all, of which I am aware, are open to strong objections and are not considered even promising by physicists.

Study of the nature of gravitation is beset with unusual difficulties; because gravitation is ever with us and about us, it is the one universal phenomenon, and we can not escape from its influence—can not obtain any outside point of view.

Gravitation is often described as a feeble force; and so it is, from one point of view. It is difficult to measure, or even to detect, attraction between two small bodies. But when the bodies are of planetary size the aggregate attraction of their molecules is enormous. It is easy to calculate that the attraction between the earth and the moon, which is just sufficient to retain the latter in its orbit, would, if replaced by a steel cable, require that the cable be about five hundred miles in diameter in order to withstand the strain. Between the earth and sun, the cable would have to be nearly as large in diameter as the earth; and attraction between the components of some double stars is millions of times greater than between the earth and sun (Lodge). So tremendous a phenomenon as gravitation, a phenomenon compared with which all others seem trivial, must have a mighty origin.

That gravitation is a phenomenon of the all-pervading ether is beyond reasonable doubt. This is so generally conceded that it need not be argued. But how does the gravitative influence originate? how is it transmitted and maintained? what is the *mechanism* of gravitation? It is the purpose of this paper to attempt an answer to these questions.

Let us consider what happens to a falling body. We know that it gathers kinetic energy from some source, as evidenced by its acceleration; that this energy may do external work or develop heat; that the amount of energy gathered is measured directly by the distance fallen through (within the limits of uniform gravitation), irrespective of the time or rate of falling. When the distance fallen through is of inter-planetary magnitude, and the attracting body large, the gathered energy

[1] Read before the American Association for the Advancement of Science, December, 1910.

is enormous; sufficient, if converted into heat, to vaporize the most refractory falling body.

We are here confronted with the question, whence comes the energy acquired by a falling body? Certainly it was not inherent in the body before the fall, as evidenced by the fact that during unimpeded fall none of the physical or chemical attributes of the body, aside from the acquired motion, changes in the slightest degree.

We have been taught that before the fall the body was endowed with "potential energy of position," which is converted into kinetic energy during the fall. I think "energy of position" is an unfortunate term because it is so very inadequate. To me, it explains nothing. The case is not like that of a flexed spring, where there is internal molecular strain or displacement.

Let us imagine a pound-weight of iron, for instance, raised from the surface of the earth to a point near the moon, in a line joining the centers of the two bodies, the point so chosen that the opposing attraction of the earth and the moon shall exactly balance each other, leaving orbital motion out of consideration.

On the surface of the earth the pound-weight had some so-called "potential energy of position" because it was capable of falling into a pit; but in its new position near the moon, this potential energy not only has not been augmented, but has disappeared entirely; the pound-weight, left free to move, remains stationary. And yet we must have expended more than twenty million foot-pounds of energy in overcoming the attraction of the earth and lifting the weight to its new position. This amount of energy would be sufficient to impart to the weight a velocity more than ten times greater than that of the swiftest cannon ball; or, if converted into heat, would be many times more than sufficient to raise the iron weight to dazzling incandescence and then vaporize it. Now, in lifting the weight, this large amount of energy has disappeared utterly. We can not believe that the whole or any part of it has been annihilated; it must, in some form, be resident somewhere. I think no one will contend that this energy is resident, in any form, in the cold, motionless pound-weight. I believe it was absorbed by, and is now resident in, the ether through which the weight was raised. Conversely, if this be true, a falling body must acquire its energy from the ether through which it falls. This is a fundamental idea to which I invite attention. Faraday glimpsed it long ago, and others have appreciated it more clearly since his time. But, so far as I am aware, no one has realized its significance.

This view of gravitation implies that the ether is endowed with very great intrinsic energy in some form. Many scientists now hold that the ether is so endowed, and that the amount of this intrinsic energy is enormous. Sir Oliver Lodge[2] appears to regard this energy as potential in form, and estimates the intrinsic energy of a single cubic millimeter of the ether to be almost inconceivably vast. He says, "All potential energy exists in the ether." Sir J. J. Thomson says, "All kinetic energy is kinetic energy of the ether."

I conceive the ethereal energy involved in gravitation to be kinetic rather than potential, the latter involving strain or stress. Newton, and later Maxwell, assumed that bodies produce a stress in the ether about them, of such nature as to account for gravitation; but they were unable to imagine any physical cause for the stress.

All the past theories of gravitation of which I am aware, except the corpuscular theory of La Sage, appear to regard gravitating matter as the seat of the gravitative influence, the surrounding ether, by induced stress or otherwise, acting simply as the medium of transmission. I can not see that any of these theories accounts for the energy acquired by a falling body.

My own view of gravitation differs from these radically. I believe that kinetic energy of the ether is the fundamental cause of gravitation; and that a gravitating body plays a secondary rôle only, in disturbing the normally uniform distribution of the ether's energy, in a manner I shall endeavor to explain later.

[2] "The Ether of Space."

Let us assume, then, that the ether is endowed with very great kinetic energy normally uniform in distribution.

Kinetic energy implies motion of something possessed of inertia. Now, inertia is a fundamental attribute of the ether. Sir J. J. Thomson holds that all inertia is inertia of the ether. The ether is highly elastic also, which, with its inertia, enables it to possess kinetic energy in wave form, as exemplified in radiation. By the term wave, I mean progressive motion locally periodic; doubtless the ether as a whole is stationary. Hence we may consider the kinetic energy of the ether as consisting in ether waves of some kind.

These waves, vast in aggregate energy, eternal in persistence, without finite source or destination, are imagined as being propagated in straight lines in every conceivable direction. This isotropic distribution of kinetic energy, essential to my theory of gravitation, was, for me, a difficult conception until I reflected that isotropic radiant energy is approximately realized in the interior of any furnace with uniformly heated walls.

Any kind of waves capable of exerting motive action on the atoms or molecules of matter will fulfil the requirements; but I shall first consider the transverse, electromagnetic waves of radiation because these are the kind of ether waves we are familiar with.

Of course intrinsic ether waves, if of the radiation kind, can not be of any frequency at present known to us as radiation, because then all bodies would become heated. But we can easily imagine them of such extremely low frequency that the molecules or atoms of matter can not respond to them—can not vibrate in unison with them—molecular resonance can not be established; hence no conversion of the ether energy *directly* into heat in the ordinary way can take place.

We are familiar with the dissipation or degeneration of the higher forms of energy into heat, and the continual degradation of heat to lower degree; that is to say, less violent molecular vibration and more general distribution. As is well known, it is only through this degradation or running down of natural energy that we are enabled to utilize some of it. Lord Kelvin called this function of energy "motivity" (we now call it entropy), and said the motivity of the universe tends to zero.

We know that ordinary radiation waves in the ether persist indefinitely and without change of frequency or direction until they encounter matter, when they are absorbed and converted into heat, only to be radiated again, usually in longer waves, to some colder body. This degradation of wave frequency continues until we can no longer follow it. I beg to suggest that the ultimate destination of this wave energy is that vast reservoir of kinetic energy intrinsic to the ether. We may liken the waves of radiant energy, which we apprehend as light and heat, to wind ripples on the surface of water, which continually degenerate in wave frequency until they are absorbed into and become a part of the mighty swell of the ocean.

Thus we may, perhaps, regard the ether's intrinsic energy as energy in its lowest form —Kelvin's zero of "motivity." But fortunately we may and do get some of this energy back in available form in several ways, as, for instance, when a falling body is arrested and develops heat; some of our wind ripples are then returned to us.

When two gigantic astronomical bodies collide under the influence of gravitation, as sometimes happens, we witness in far distant space the birth of a nebula. The inconceivably vast amount of heat developed by the collision converts both bodies into luminous vapor which expands with incredible rapidity into the nebulous cloud. This heat energy must in course of time degenerate back into the ether whence it came, though billions of years may be required; and during all this time the energy has "motivity." We may picture the stupendous result of the collision as only a local splash in the ether's mighty ocean of energy.

Having postulated that the ether is endowed with very great intrinsic kinetic energy in wave form of some kind; that the waves are

propagated in straight lines in every conceivable direction, *i. e.*, the wave energy is isotropic; and that this energy is distributed uniformly throughout the universe except in so far as the distribution is disturbed by the presence of matter, I shall endeavor to explain my conception of the mechanism of gravitation.

For illustration in terms of the known, let us imagine a closed space having uniformly luminous walls of such character that every point on their surface radiates light in all internal directions. The enclosed space may be of any shape, but for the sake of simplicity let it be spherical or cubical, and large, say as large as a lecture room. The space will be filled with isotropic radiant energy uniformly distributed—any cubic centimeter of space containing as much energy as any other.

Next let us picture a small opaque body suspended anywhere in our luminous space. The body may be of any shape we may imagine an atom or molecule to have; but, again for simplicity, let it be spherical—say a small grain of shot, and let it be located near the center of the space.

The small body will absorb the light which falls upon it and will cast a spherical shadow, the depth or intensity of which will vary inversely with the square of the distance from the center of the body; and the shadow will extend to the confines of the enclosure, however large the latter may be. We can not perceive the shadow, but we know it is there. It is true that the body will soon acquire the temperature of its surroundings, and radiate as much energy as it receives; but for the purpose of this illustration let us consider only the high-frequency light energy.

As is well known, the ether waves of light will exert a slight pressure on the body. But in the case supposed, the pressure will be equal on all sides and no effort toward translation can result.

Now let us introduce a second small body, similar to the first, and some distance from it. This, also, will cast a spherical shadow like the first. The two shadows will intersect, and each body will lie within the shadow of the other. In other words, each body will be partially shielded by the other from the ether waves coming from that direction. Hence the light pressure will be less on that side of each body which faces toward the other than on the side which is turned away, and the bodies will be urged toward each other by the excess of light pressure on the sides turned away. This excess of pressure will vary with the inverse square of the distance between the centers of the bodies so long as the ratio of distance to diameters remains large.

The ether waves concerned in gravitation can not, however, be like the light-waves I have just used for illustration, because light-waves heat bodies on which they fall; and their pressure is almost wholly superficial, it does not reach molecules much below the surface, and hence bears little relation to mass.

But let us substitute for the short and feeble waves of light, powerful waves, still of the radiant kind, but of such great length and slow frequency that, as before explained, they do not excite the molecular vibrations which we appreciate as heat, and hence are not absorbed by matter; they pass freely through all bodies, bathing the interior molecules as effectually as those on the surface.

Under these conditions each molecule or atom or unit of a gravitating body will have its own spherical shadow or field of influence, and the gravitative force acting on the body will vary directly with the sum of its units, *i. e.*, with its mass.

The spherical shadow which I have pictured as the field of influence of each atom or material unit implies that the atom has caused, principally in its immediate neighborhood, a diminution of the ether's energy. Let us further imagine this subtracted energy resident in the atom as kinetic energy of translation in many paths, almost infinitesimally short and in every direction, but without collisions because neighboring atoms follow *very* nearly parallel paths. We may then picture the collective atoms or molecules of matter buffeted about in every direction by the ether waves in which they are entangled, like a suspended precipitate in turbulent water.

Each atom or molecule may be regarded as a center of activity due to its kinetic energy of translation, with continual absorption and restitution of the ether's energy, normally equal in amount. The manner in which this molecular activity maintains, in effect, the supposed spherical shadow requires explanation which I shall attempt in a future paper.

Of the several components into which the composite motion of each atom can be resolved, that one lying in the direction of an attracting body will be the greatest, because the waves from that direction, being partially intercepted by the attracting body, are weakest; and the atom will be *pushed* in that direction by the superior waves behind it. If free to fall, the atom will continually absorb more energy from the stronger waves behind it than it restores to the weaker waves in front, and will thus acquire additional kinetic energy of translation in the line of fall, measured directly by the number of waves involved, *i. e.*, by the distance moved. Conversely, if the atom be forced away from the attracting body, restitution of energy will exceed absorption, and the energy expended in moving the atom against attraction will be transferred to the ether.

It will be seen that gravitation is a *push* toward the attracting body, and not a pull. It is clear, also, that the velocity which a falling body can acquire tends asymptotically to a limit, which is the velocity of the ether waves which push it—the velocity of light, if transverse waves are involved.

I have already intimated that any kind of ether waves capable of imparting motion (not internal vibration) to the atoms of matter will fulfil the requirements of my theory, but have thus far discussed only transverse waves.

Let us now consider longitudinal waves—waves of compression and rarefaction, like sound waves in air and in elastic liquids and solids. The "spherical shadow" conception which I have employed in connection with transverse waves applies equally well here.

So far as I am aware, longitudinal waves in the ether are unknown; but that such waves have not been observed is not convincing argument that they do not exist.

Assuming then that some, or perhaps much, of the intrinsic energy of the ether is embodied in longitudinal waves, we have only to find some motive action of such waves on atoms of matter to account for gravitation. Adequate motive connection may perhaps be effected by the locally alternating flow and ebb—acceleration and retardation of the ether in which the atoms are enmeshed, incident to its wave motion. We have ample reason for believing that the ether does obtain a grip of some sort on the atoms of an accelerating (falling) body, and a retarding (rising) body, from which it follows that accelerating and retarding ether, as in a wave of compression, must grip a comparatively stationary atom.

Certain facts of astronomy apparently require that gravitational attraction between bodies, however distant from each other, must, in effect, be instantaneous; that is to say, the line of apparent attraction between them is a straight line joining their centers. I believe my theory meets this condition, but I shall reserve discussion of the point for a future paper.

I feel much diffidence in presenting the foregoing rough draft of a theory of gravitation; but I can not avoid the belief that it contains some germs of truth, perhaps the real key to the great mystery, though, if this be true, I have, no doubt, used the key clumsily and imperfectly.

If the ether-wave theory of gravitation is, in the main, the true one, it offers some hope of experimental verification. Provided the waves are of one principal frequency, or even of several, we may find something, doubtless of molecular magnitude only, which will oscillate in unison with them so that resonance can occasionally be established and a cumulative effect obtained sufficient to manifest itself as heat.

In searching for some natural phenomenon of this nature, I thought of the thermal condition of the upper atmosphere as a possible case. The mean molecular velocity of a gas at some temperature, in connection with the

mean free path of its molecules at some particular pressure or pressures, may possibly afford the necessary conditions for fortuitous resonance, with development of some slight amount of heat by the increased violence of inter-molecular collisions. I have done much experimental work on these lines during the past year, but, notwithstanding refinement of method and manipulation, the results have thus far been unsatisfactory. The work is still in progress, however, and investigation of other phenomena is contemplated.

CHARLES F. BRUSH

CLEVELAND, OHIO

AMERICAN SOCIETY OF ZOOLOGISTS
EASTERN BRANCH

THE Eastern Branch of the American Society of Zoologists held its annual meeting on December 27–30, 1910, inclusive, at Cornell University, Ithaca, N. Y., in conjunction with the American Society of Naturalists, the American Association of Anatomists and the Society of American Bacteriologists.

The following officers were elected:

President—H. V. Wilson, University of North Carolina.

Vice-president—H. E. Crampton, Columbia University.

Secretary-treasurer—Raymond Pearl, Maine Agricultural Experiment Station.

Additional Member of Executive Committee—R. G. Harrison, Yale University.

The following persons were elected members of the American Society of Zoologists at this meeting: Dr. Alice M. Boring, University of Maine; Dr. O. A. Johannsen, Maine Agricultural Experiment Station; Professor R. E. Sheldon, University of Pittsburgh; Professor A. E. Lambert, State Normal School, Framingham, Mass.; Dr. R. C. Schiedt, Franklin and Marshall College; Dr. Sergius Morgulis, Harvard University; Professor E. W. Gudger, State Normal College, Greensboro, N. C.; Dr. A. M. Banta, Carnegie Institution, Station for Experimental Evolution; Professor G. G. Scott, College of the City of New York.

A committee was appointed to prepare a resolution on the death of Professor C. O. Whitman. This resolution will be published in a later number of SCIENCE.

The following papers were presented at the meeting, either in full, or by title:

The Spermatogenesis of the Opossum: H. E. JORDAN, University of Virginia.

An accessory chromosome and chondriosomes are the structures of special interest. Metaphase plates of dividing spermatogonia contain 17 rod-shaped chromosomes (diploid group; 16 autosomes, 1 monosome). A chromatin- (chromosome) nucleolus is present during the growth period (including synizesis and synapsis) invariably at that point near the nuclear membrane next the centrosphere. The first numerical reduction results from a pairing end to end (telosynapsis) of the 16 autosomes. The haploid chromosome group thus contains 9, the accessory recognizable by its larger size and bipartite form. During metakinesis (reduction division) the accessory chromosome passes undivided, and in advance of the ordinary chromosomes, to one pole. Two types of secondary spermatocytes result: one with 9, the other with 8 chromosomes. During the brief resting phase one type has a chromatin-nucleolus, the other lacks this structure. A second numerical reduction has occurred—a phenomenon previously described by Bardeleben (1898) for man, and quite recently by Guyer for certain birds—giving rise to hemioid groups containing 5 and 4 chromosomes, respectively. The ensuing division is equational. In the early spermatid-phase a resolution takes place giving 9 and 8 chromosomes, respectively. A dimorphism of spermatozoa thus results. Chondriosomes (mitochondria) appear in early postsynaptic stages (probably as chromidia passed out of the nucleus). A direct continuity is demonstrable between the chondriosomes and the spiral filament of the middle piece of the spermatozoon. No twin spermatozoa, such as Selenka described in the vas deferens of the opossum, appear in the testes studied.

The complete paper will appear in the *Archiv für Zellforschung.*

The Germ Cell Determinants of Beetles' Eggs: ROBERT W. HEGNER, University of Michigan.

This report is based on the results of experiments in killing parts of the eggs of some chrysomelid beetles. The posterior ends of freshly-laid eggs contain a disc-shaped mass of granules that stain like chromatin. These granules are taken up by the cleavage products that encounter them; these cleavage products later become germ cells. For this reason the granules have been called germ-cell determinants. When the posterior ends of freshly-laid eggs are killed with a hot needle, thus preventing the granules from taking part in